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The Research on Pulsation of Pump Pressure in Water Mist System

Xu Zhenyu*, Miao Xuhong, Zuo Hai

Naval Academy of Armament, China

Abstract

It is very important to maintain the stability of pump pressure in water mist system for higher fire suppression efficiency. In recent years, the optimization of design of the multi-plunger pump to reduce the pulsation of output pressure is an urgent problem to be solved. In the present study, the flow pulsation and frequency characteristics of multi-plunger canted disc link pump were simulated based on the kinematical equations. The kinetic characteristics of this type of pump were expounded through the calculation results. The effects of plunger number, canted disc dip angle, rotate speed, diameter and location of ball socket reference circle on the flow pulsation and frequency characteristic of the pump were also studied.

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Keywords: multi-plunger pump, pressure, pulsation

1. Overview of the object studied

The pump in water mist system is a 7-plunger valve type orifice pump，and the schematic is shown in Fig.1. The pump is mainly made of baseplate, cylinder block, canted disc, bent axle, gearbox, link, plunger, plunger sleeve, accumulator, and bellows.

The advantages of this type of pump are:

1) The friction is reduced. The two key friction places are between the plunger and plunger knot, and between the plunger connecting rod and inclined plate. The friction is reduced compared with the common plunger pump with inclined plate.
2) It is sphere connecter between the connecting rod and inclined plate, plunger. The friction coefficient is reduced.
3) This type of pump is simple in configuration, and have a small size. The self-sucking power is strong. The volume and mechanical efficiency is high as 95%.

* Corresponding author. Tel.: Xu Zhenyu
E-mail address: dayutiantangyu@163.com

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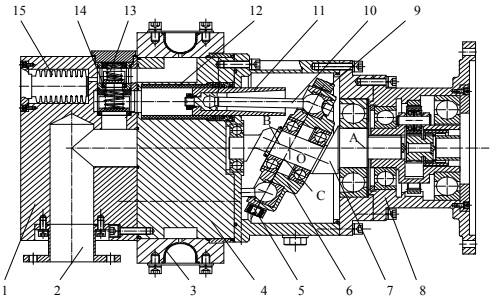

1-bottom plate; 2- sucking entrance; 3-energy storage device; 4-cylinder case; 5-directing slipper; 6-inclining plate; 7-bent axle; 8-speed cut device; 9-directing ring; 10-connecting rod; 11-plunger; 12-plunger knot;13-compressing valve； 14-sucking valve; 15-corrugated pipe

Figure 1. The schematic of the pump with plungers.

2. The pulsation characteristics of flow rate

The flow rate of other common odd-number plunger pump can be expressed as:

$$q_t = \frac{2\pi A R_z n tg\phi}{60} \sum_{j=1}^{z_0} \sin\phi_j \tag{1}$$

where q_t is the output flow rate of the pump, R_z denotes the radius of the distribution circle of plungers, ϕ_j is the angle of n-th plunger locating at the drain area, z_0 means the amount of plungers locating at the drain area.

2.1 The influence of the location of ball socket of inclined plate on the flow pulsation

Figs. 2-4 show the simulation results by varying the intersection angle between OB and OC. It shows in Figs. 2-4 that, the flow pulsation differs when a_0 (denoting the location of ball socket of inclined plate) is different. For the pump with 6 plungers, when a_0 equals π/6, the pulsation of flow rate is small. For the pump with 7 plungers, when a_0 equals π/14, the pulsation of flow rate is small. For the pump with 8 plungers, when a_0 equals π/8 or zero, the flow pulsation is small. This means the pulsation of flow rate can be reduced by design a_0 to be a reasonable value. Moreover, it shows in frequency characteristics of flow pulsation the frequency characteristics is independent of a_0, but the fundamental frequency is related to the amount of plungers.

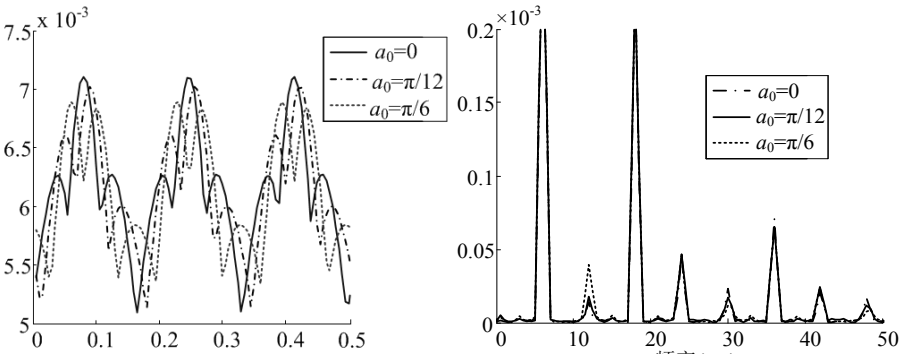

Figure 2. The pulsation of flow rate of the pump with 6 plungers under different a_0.

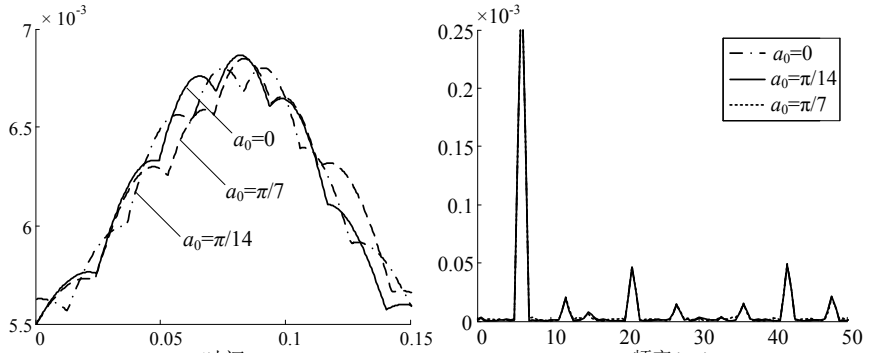

Figure 3. The pulsation of flow rate of the pump with 7 plungers under different a_0.

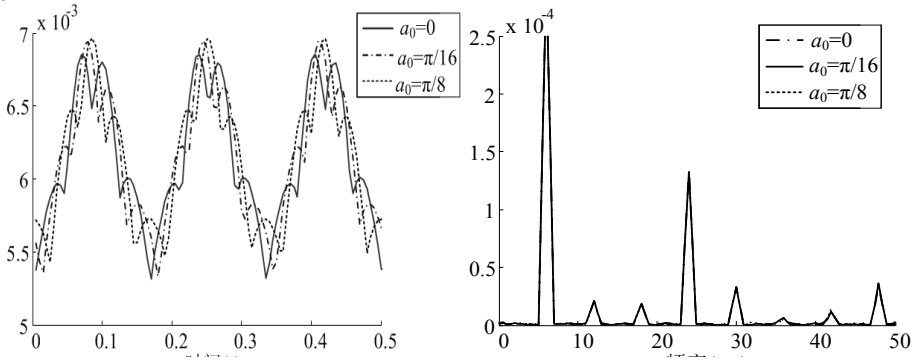

Figure 4. The pulsation of flow rate of the pump with 8 plungers under different a_0.

2.2 The influence of the amount of plungers on the flow pulsation

The effect of the amount of plungers is examined by varying the amount of plungers and keeping the flow rate constant. It is examined under different rotating speed of pump n, inclined angle ϕ, and the radius of pitch circle of ball socket. The numerical results show that, keeping the flow rate constant, increasing the amount of plungers and decreasing the inclination angle can reduce the flow pulsation effectively. Increasing the amount of plungers and decreasing the rotating speed and the radius of pitch circle of ball socket have minor effect on flow pulsation. When the inclination angle is the same, the flow pulsation in the pump with odd-number plungers is smaller than that in the pump with even-number plungers. Furthermore, when the amount of plungers and the rotating speed vary, there are two fundamental frequency for the flow pulsation. The lower frequency is related with the amount of plungers, while the higher frequency is 21Hz. The results show that the fundamental frequency is 3Hz for the pump with 9 plungers, which is obviously different with the case of 6-8 plungers. Moreover, the fundamental frequency is independent of the inclination angle and the radius of pitch circle of ball socket.

2.3 The influence of the inclination angle of inclined plate on the flow pulsation

The numerical results show that the pulsation of flow rate decreases with decreasing inclination angle of the inclining plate. When $\phi = 25°$, the pulsation rate is 0.18; while $\phi = 21°$, the pulsation rate decreases to 0.16. Decreasing the inclination angle and increasing the radius of pitch circle of ball socket simultaneously can still decrease the pulsation of flow rate. The frequency characteristics of flow pulsation show that when the rotating speed is 180r/min, the fundamental frequency of flow pulsation of pump with 7 plungers is about 6Hz. The fundamental frequency has no relations with the inclination angle of inclined plate and the radius of pitch circle of ball socket.

2.4 The influence of rotating speed on the flow pulsation

The pulsation of flow rate of pump with 7 plungers under different rotating speed is simulated and the results show that the pulsating frequency of flow rate of the pump equals to n/30, where n is the rotating speed of bent axle (r/min). Under four different rotating speed, the pulsation rates are all 0.22. The pulsating frequency of flow rate equals that of rotating speed, and the pulsation rate is independent of rotating rate. Decreasing the inclination angle and increasing the rotating speed can decrease the flow pulsation. When keeping the specified flow rate constant, decreasing the inclination angle can decrease the flow pulsation no matter how other parameters vary. The frequency characteristics show that the fundamental frequency of flow pulsation is mainly dependent on the plungers and rotating speed.

3. Comparison with the experimental results

The experiments were performed on pumps with 7 plungers, whose the working conditions are n=400r/min, ϕ=25°, R=98mm and n=180r/min, ϕ=25°, R=112.25mm, respectively. Both conditions have the identical specified flow rate. The pressure pulsation plots under the working pressure of 3.5MPa are obtained, shown in Fig. 5(a)

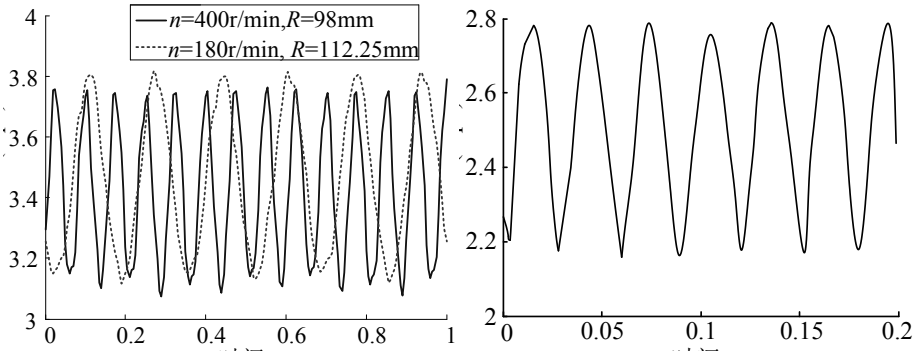

Figure 5. The pulsation of pressure for the pump with (a) 7 plungers and (b) 8 plungers.

Under the output pressure of 2.5MPa, the pump with 8 plungers was tested with the working condition of n=1000r/min, ϕ=15°. The flow rate is 320L/min and the diameter of plunger is 36mm. The test results are shown in Fig. 5(b). It can be seen from the pressure pulsation plots of the pump with 7 plungers under different rotating speed, the variation of rotating speed has minor effects on the pressure pulsation. The rotating speed is higher, the pulsation frequency is higher. The pulsation frequency is identical with the frequency of rotating speed. The pulsation frequency equals n/60. Fig. 5(b) shows that the pressure pulsation rate of the pump with 8 plungers and the inclination angle of 15° is smaller than that of pump with 7 plungers and the inclination angle of 25°: the former is 0.133 and the latter is 0.203. Hence, considering the simulation results, it can be concluded that decreasing inclination angle of inclining plate can decrease the pulsation rate of flow rate.

4. Conclusions

The displacement, velocity and acceleration of plungers in the plunger pump are calculated based on the kinetic equations. The flow pulsation and frequency characteristics of the pump with multi-plungers are also simulated. The kinetic characteristics of the pump with multi-plungers are discussed. The effects of the amount of plungers, inclination angle of inclining plate, rotating speed, the radius of pitch circle of ball socket and the distribution locations of ball socket on inclining plate, on the pulsation of flow rate and frequency characteristics are studied.